Flood and heatstress modelling for climate adaptation, results of 'Stressttest Fryslân'

Floris Boogaard[1], Jan Fliervoet[2], Doutsen Krol[1], Jeroen Lasonder[3], Karel Veeneman[4], Pietrik Hoornstra[5]

[1] Hanze University of Applied Science, Spatial transformation, Groningen, The Netherlands
[2] VHL University of applied science, The Netherlands
[3]Tauw Group, department Assen, The Netherlands
[4] Wetterskip Fryslân, The Netherlands
[5] Municipality Leeuwarden, The Netherlands

Abstract
Urban planners and several stakeholders in public and private sector are in need of (quickscan) tools that can assess the vulnerability to floods and thermal stress. Urban flooding and thermal stress have become key issues for many cities around the world. With the continuing effects of climate change, these two issues will become more acute and will add to the serious problems already experienced in dense urban areas around the globe.
The present paper presents a large scale 'stresstest' that deals with the combination of innovative tools to address these challenges. For the whole province of Fryslân in The Netherlands flood maps and heat stress maps were developed and used for the comparison analysis. Concrete priority problem locations where located with models and climate adaptive measures were selected in masterclasses in the period of January 2017 to June 2018 in a triple helix consortium. The scale of this climate adaptation stresstest is considered the biggest and detailed in the world due to the high tech computing and the participation of all stakeholders involved.
The masterclasses help stakeholders to follow the 3 step climate adaptation strategy 'analyse, ambition, act' with a focus on the first step 'analyse' that raises awareness and provides insights on the resilience to climate change of a specific area. The first evaluation of the applied tools and project results and by the stakeholders is positive. The project raised awareness on climate adaptation and delivered a calibrated stresstest for Fryslân with detailed calculations of flood risks and heatstress in the city. Best practices and climate adaptation strategies are created in masterclasses. Stakeholders have a detailed insight in the vulnerability and resilience of their district and have concrete examples and plans to implement climate adaptation measures in the near future.

INTRODUCTION

In The Netherlands, the adaptation strategy 'analyse, ambition, act' is often applied. All municipalities in the Netherlands must conduct a stresstest in the coming two years to identify bottlenecks in areas such as flooding and heatstress. This is stated in the so-called Delta Plan for Spatial Adaptation, which was presented in The Hague at the end of 2017 [1]. In order to take the steps from 'analyse' to 'act', a project was set up: the stresstest Fryslân with masterclasses for climate adaptation. In stresstest Fryslân a 'triple helix' composition (governments, companies and knowledge and educational institutions including young professionals and students) reviews the status of climate adaptation in their district in a short period of time. The status of climate adaptation in a municipality with various stakeholders is evaluated with concrete measurements and results.

Pilot area Fryslân

Fryslân is a province in the northwest of the Netherlands (figure 1). It is situated west of Groningen, northwest of Drenthe and Overijssel, north of Flevoland, northeast of North Holland, and south of the North Sea. In 2010, the province had a population of 646,000 and a total area of 5,100 km^2 (2,000 sq mi). The capital and seat of the provincial government is the city of Leeuwarden, a city with 91,817 inhabitants. The province is divided into 20 municipalities. The official languages of Fryslân are West Frisian and Dutch.

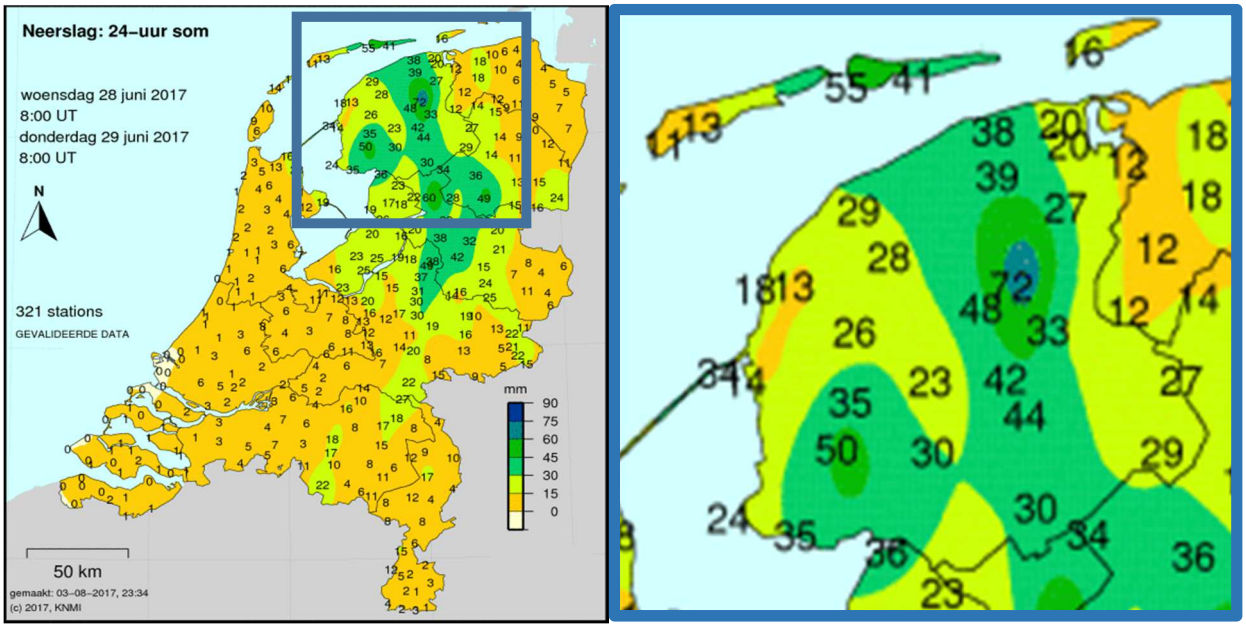

Figure 1 map of the Netherlands with daily rainfall (left), selection of area of stresstest Fryslâan indicating a 72 mm/day rainfall (source: www.knmi.nl) .

Almost all of Fryslân is below sealevel, meaning the groundwater tables are high in the (urban) areas. For this reason the infiltration capacity of stormwater is expected to be very low in Fryslan, also since most of the soil is characterized as (sandy) clay. Nevertheless multiple stormwater infiltration facilities have been implemented in the low lying parts of The Netherlands that contribute to climate adaptation, figure 5 [2].

Stakeholders

In order to take the steps from 'analyze' to 'action' in the Dutch 3 step climate adaptation approach it is important to involve a 'triple helix' consortium: public (governmental organisations), private (companies) and knowledge and educational institutions that involve young professionals and students ‘the champions of change in climate adaptation’ for the future. The stakeholders of stresstest Fryslân can be found in table 1.

Table 1 stakeholders stresstest Fryslân

Triple helix	**organisation**
Academia	VHL university of applied sciences Hanze university of applied sciences Groningen
Public	20 municipalities water authority ‘Wetterskip Fryslân’ Province of Fryslân (all public parties are combined in the organisation KCNL)
Private	Tauw Group (Technical Advice Union of Water authorities)

Aim of the Project

The overall aim of this project is to provide insight into the possible effects of climate change, such as flooding (flooding) and heat stress by developing a climate stress test (simulation model) for the province of Fryslân:

- Insight into flooding and heat stress for cities in Fryslân.
- Prioritizing and substantiating climate adaptation strategies
- Stimulating participatory area development

To achieve this aim the project will:

- Develop and supervise stresstests for flooding and heat stress
- Prepare and perform climate adaptation masterclasses and advise all (20) municipalities where climate adaptive measures are required
- Develop and apply tools (part of the method) that help to achieve the aims of the project.

Method and tools

For the **flood map** of the province of Fryslân, the Calamity Levels of Urban Drainage Systems (CLOUDS) tool was used. This is 'quick-scan' method to simulate storm water floodings. CLOUDS is based on the assumption that for a cloud burst (> 60 mm/h) most of the stormwater will flow and stay above ground. CLOUDS visualizes the streamlines and the depth of stormwater in depressions where water will accumulate. The quick-scan is based on only readily available data. The most important is an accurate DEM, which is freely available for the whole of the Netherlands (AHN3). With 9 points per square meter and a vertical accuracy of several centimetres this provides an insight in the surface elevation [3].

The quick-scan GIS-based **thermal stress maps** have been developed in The Netherlands in order to give a quick insight in possible thermal stress locations in a city. It is based on accurate DEM and the assumption that for a quick insight of thermal stress some rough simplifications of the actual physical processes can be made. The maps give an estimate of the maximum PET (physiological equivalent temperature) during a heat wave. Such maps have also been made for other European cities, Africa (Johannesburg) and Asia (Thailand and Taiwan) [4].

Masterclasses have been set up to discuss the results of the floodmaps and thermal stress maps and come up with concrete measures for climate adaptation [5]. All municipalities have taken part in a triple helix consortium (table 1) discussing vulnerable flooding spots and planning of sustainable urban drainage systems (SUDS) to minimize these floods. The program of the masterclasses is adjusted to specific challenges and ambitions of the stakeholders. But in general the workshop consist of first part with a general instruction on working with heatstress and flood maps. The second part deals with comparing local knowledge with the models for the specific region and starting to develop a climate adaptation strategy based on 'analyse, ambition, act' (figure 2).

Figure 2 impression of masterclasses: (left) giving info on model output and tools for Fryslân (right) applying this knowledge in triple helix consortia.

To take the step from ‘analyse & ambition’ to ‘action’, stakeholders have used tool **climatescan** to map Best Management Practices (BMPs) of already implemented climate adaptation measures with detailed information (location, photo and film material and download links to more information). Climatescan is an interactive online map application that provides an easy-to-access database of international project information in the field of urban resilience and climate adaptation. The tool is able to support the tasks of prioritising risks, evaluating flood models, designing appropriate remedial measures and map several sustainable urban drainage systems. The tool is used in the masterclasses to serve the needs of different stakeholders from several international projects as: INXCES and Interreg projects: WaterCoG and Sponge2020. Climatescan is used in the masterclasses Fryslân as an interactive web-based map application for international knowledge exchange on ‘blue-green’ projects in Fryslaân and around the globe.

RESULTS

The flood maps indicated vulnerable low-lying areas, whereas thermal stress maps indicate open, unshaded areas where high Physiological Equivalent Temperature (PET) values (thermal comfort) can be expected. The work indicates the potential of combining two different kinds of maps to identify and analyse the problem areas. The suggested solutions for climate adaptation varied along the different areas in Fryslân (due to social and hydrologic differences).

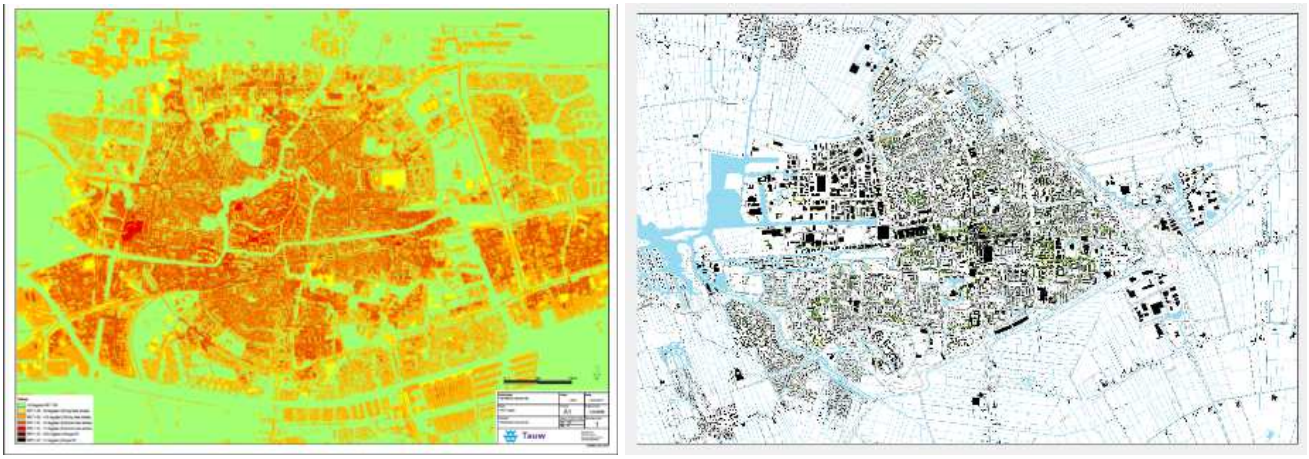

Figure 3 results of heat stress (left) and flooding mapping (right) on district level for urban planners to prioritize the implementation of climate adaptation measures

Combining the elevation model, the dataset with buildings and aerial photographs a 3D model of some cities in Fryslân is created to get an improved overview of the outcomes of the model. The model was shown in the 3D virtual reality theatre on a cylindrical screen using 6 HD projectors to project an image with a resolution of roughly 5000x1800 [6]. The software was running simultaneously on 7 PC's, one master PC for the control of the model and 6 slave PC's to drive the projectors After the flood modelling, the heat stress was visualized in 3D (figure 4). These visualisations and interactive communication tools can be used to encourage knowledge-sharing of climate-proofing and urban resilient projects.

Figure 4 3D visualisation helps engagement of the stakeholders and after a first pilot will be further implemented in the next steps of the project [6].

The application of tools as storytelling and open source website climatescan has proven to be helpful not only for the leading and involved academics of this project (PhD-students, lecturers and researchers) but also for practitioners working in this field (triple helix: private, public and research institutes). At the time of the masterclasses climatescan had over 10.*000 users and more than 2500 international projects [5].* More than 60% of the users is younger than 34 years and 51% female users resulting in engagement with an important target group: young (female) professionals. 138 BMPs where mapped in only the Fryslân area on climate adaptation, 350 different BMPs where mapped in the Northern part of The Netherlands and almost 1150 in the entire Netherlands.

Figure 5 results of mapping of BMP's in the (North East) part of the Netherlands [5].

Based on the insight in the vulnerable flooding spots the municipalities have planned to implement some sustainable urban drainage systems (SUDS) to minimize these floods. The municipalities are advised to reduce the vulnerability to flooding by reshaping some streets during reconstruction of the area. Those streets will be designed in such a way that they can convey the excess storm water without causing flood problems. Although the heat stress maps didn't lead to many plans for implementation of measures, they were mainly used to get attention for the issue of heat stress and to see the differences within the province of Fryslân. The municipalities acknowledged the added value of heat stress restricting measures for improving the quality of life.

During the masterclasses the participants also addressed the importance of creating awareness and involvement of inhabitants to apply measures and to make an inventory of problem areas (e.g. using social media). Specific attention should be payed to large companies, care institutions and housing corporations due to their large paved area and effects on too much water and heat. This awareness is also needed in other departments of the municipalities because climate adaptation is an issue which concerns us all and needs an integral approach (and maybe a different type of financing).

A lot of municipalities miss a review framework to determine water (and heat) nuisance and to decide when to take action. A vision or Climate Adaptation Plan could help in these situations and also with new spatial plans the vision could be consulted so No Regret measures can be taken to create a more resilient situation in the future. Suggested is to make such a Climate Adaptation Plan for the complete province of Fryslân, Municipalities don't have to do this by themselves, after all we can learn from each other and only by acting together we can increase the awareness and apply climate adaptation measures.

Implementation climate adaptation measures is not an easy task in the existing urban dense areas of many municipalities in Fryslân. Applied universities published practical guidelines for design, implementation and maintenance of BMPs in low lying areas of The Netherlands and beyond.

In conclusion, the outcomes of this project have shown there is a clear demand for a collaborative, knowledge sharing tool where first impressions of different urban resilience projects can be quickly gained.

- More insights in the 'analyse' phase of the climate adaptation strategy for the province of Fryslân based on the models of the stresstest
- Shared learning and cooperation between municipalities is necessary to develop a climate adaption plan
- Story Maps can be supportive in creating a shared knowledge platform, including the input of local knowledge
- Masterclass created awareness about climate adaptation among public servants and aldermen, especially the interaction between different departments within one governmental institution was important to create shared responsibility. Not only the public servant for water is responsible, but also the departments of engineering, green, monitoring and maintenance etc..

Next steps

The flood- and heatstress maps could be further improved and used by urban planners and other stakeholders to assess the resilience and well-being of cities. The (story) maps of Fryslân will be combined with other GIS data from other projects and made available for all stakeholders. The work presented shows that the combined analysis of such maps also has a strong potential to be used for the analysis of other challenges in urban dense areas such as air and water pollution, immobility and noise disturbance.
Further involvement and awareness of stakeholders can be created by a planned City Climatescan in Leeuwarden and other Fryslân cities which is a methodology to measure, map, scan and assess different parameters that provide insight into the vulnerability of urban areas and neighborhoods [7]. The method and new insights from this project could be incorporated in the legislation and new policy plans "Omgevingswet" in 2019.

Aknowledgements

The stresstest was made possible through the cooperation of all mentioned stakeholders (table 1) and tools from EU projects as WaterCoG and INXCES.

References

[1] Delta program: www.deltacommissaris.nl/deltaprogramma/inhoud/deltabeslissingen/deltabeslissing-ruimtelijkeadaptatie consulted 28 March 2018.

[2] F. Boogaard , J. Tipping , T. Muthanna , A. Duffy , B. Bendall , J. Kluck ., Web-based international knowledge exchange tool on urban resilience and climate proofing cities: climatescan, 14th IWA/IAHR international conference on urban drainage (ICUD), 10-15 September 2017, Prague.

[3] Floris Boogaard, Jeroen Kluck , Govert Schoof, Michael Bosscher, The need for INnovations for eXtreme Climatic EventS (INXCES), the progress of flood modeling case Bergen Norway, Procedia Engineering Volume 209, 2017, Pages 56–60, https://doi.org/10.1016/j.proeng.2017.11.130, Elsevier 2017

[4] Boogaard F., Vojinovic Z., Yu-Cheng C., Kluck J. Lin T., High resolution decision maps for urban planning: a combined analysis of urban flooding and thermal stress potential in Asia and Europe, ICSEWR, Melaka. Malaysia December 2016.

[5] Boogaard F, Klomp T, Maneschijn M., 'Masterclasses klimaatbestendig inrichten', H2O-Online / 21 maart 2016.

[6] M. Verlaat, L. van der Meulen, G. Schoof, F. Boogaard, J. Kluck, Disaster Risk Management: Urban Flooding and heatstress, Geomatics Workbooks n° 12 – FOSS4G Europe Como 2015, (2015)

[7] Boogaard F, Heikoop R, Bosscher M, Akkerman O., Research results of a new governance method in climate adaptation; the international City Climate Scan Rotterdam, RRAU (Resilient Responsible Architecture and Urbanism), Groningen, 10-12 April 2018.